

**IMPACT VS. POST-IMPACT METAMORPHOSIS IN IMPACTITE GARNET;**

Jouko Raitala, Department of Geosciences and Astronomy, University of Oulu, Oulu, Finland;  
jouko.raitala@oulu.fi

There are two possible impact-related phases which may result in the observed cation exchange between various crystals and/or matrix. An extremely fast (in geological terms, of course) cation exchange or depletion may have taken place during the high-pressure shock or vibration phase immediately following the impact. Another possibility is an impact-induced high-temperature post-impact environment which may result in extended diffusional cation exchanges between remained crystals and the milled or even melted matrix material. Both processes are possible but it may be rather difficult to distinguish between them. The first high-pressure phase may be most effective between two or three most active mineral phases present in the shocked rock. The following hot low-pressure phase may favour additional cation exchange between the remained crystals and the crushed matrix. Both effects may be limited to crystal edge zones with shortest diffusive distances. Cation migration paths through the whole crystal lattice are slower and more difficult. High temperatures and concentration gradients increase diffusion coefficient and the cation migration.

In a recent experimental study Feldman et al. [1] found shock metamorphic changes in chemical composition of feldspars. In the diaplectic mineral zone there was a fracturing increase within crystals. The second amorphous zone had concentric and radial fractures which crossed crystal boundaries. The area with highest shock metamorphism was impact glass melt. The zone boundary pressures were 30 and 60 GPa, respectively. The most interesting detail was that the feldspar composition, which remained basically unaltered until 25 GPa, suffered from cation migration which increased by increasing shock pressure. A clear K and Na exchange was found between albite and K-feldspar while there was also an overall cation outflow from feldspars. Their suggestion to use the width of this cation exchange zone as a shock-metamorphic geobarometer is interesting and should be studied in details as well as the process which allows the cation exchange itself during an extremely short impact shock event.

Garnets are other interesting impactite minerals in this respect. They are ideal for detailed studies because they are common, more impact-resistant than most other minerals and their composition and zoning can be easily studied. Being bulky, closely packed hexoctaedral nesosilicates garnets are rather stable and resist rather high pressures. They are commonly the most intact impactite mineral phase if present in the original mineral assembly. Compared to other common rock-forming minerals of an impactite garnets have suffered of only minor mechanical fracturing. Their zoning makes, however, it rather difficult to find the exact amount of impact-influenced compositional effects.

The garnets of staurolite-garnet schist bedrock and their impactite varieties of the Jänisjärvi impact crater (61.58°N, 30.55°E [2]) were (and are still) studied in order to analyze impact-related metamorphic changes. Garnets look rather fresh and intact in the impactite rocks studied. The original garnet composition reflects the high-T,P areal metamorphic environment. With increasing metamorphism garnets of the pyrope group change from grossularite ( $\text{Ca}_3\text{Al}_2\text{Si}_3\text{O}_{12}$ ) and spessartite ( $\text{Mn}_3\text{Al}_2\text{Si}_3\text{O}_{12}$ ) to almandine ( $\text{Fe}_3^{2+}\text{Al}_2\text{Si}_3\text{O}_{12}$ ) and pyrope ( $\text{Mg}_3\text{Al}_2\text{Si}_3\text{O}_{12}$ ) [3]. This study describes probable impact-related diffusional changes found in Jänisjärvi garnet compositions. The FeO, MgO, MnO<sub>3</sub> and CaO abundances in various garnets were analysed as point profiles from crystal edge to the centre. Abundance in the crystal centre was set to one unit. Barbs indicate possible diffusion direction.

	Original garnet				Shocked garnet			
	edge		centre		edge		centre	
FeO	1.07	> 1.02	1.01	1	-> 1.15	>> 1.04	> 0.97	1
MgO	1.17	> 1.04	> 1	1	-> 1.73	>> 1.58	> 1.20	> 1
MnO	0.62	< 0.93	< 1.00	1	<- 0.33	<< 0.84	< 1.12	> 1
CaO	0.90	< 0.94	< 0.97	< 1	<- 0.59	<< 0.69	< 0.90	< 1

**Impact vs. Post-Impact Metamorphism in Impactite Garnet: Jouko Raitala**

In the almandine garnet (72.5-83.2% al-component)  $\text{Fe}^{2+}$  and  $\text{Mg}^{2+}$  are higher at the edge and lower in the centre of shock metamorphic garnet than in the unaltered ones while  $\text{Mn}^{2+}$  and  $\text{Ca}^{2+}$  are relatively lower near the border and higher in the centre of shocked garnet than in the unaltered ones. The exact numbers shown above represent only one sample but very similar analyses have also been obtained from samples from several other locations. The number of the samples is, however, still too low in order to provide a statistical importance high enough to get the actual diffusion rate.

The share of the two alternative metamorphosis (shock-metamorphosis in the impact event and thermal post-impact metamorphosis) has to be re-thought after the observations of the Feldman group [1]. Previously it was suggested [4] that the late impact-induced high-temperature environment was responsible for diffusional cation exchange between garnet crystals and the surrounding matrix during the thermal post-impact period. Low pressure is proposed to favour the Mn, Ca outflow and Fe, Mg inflow at garnet's edge zones. The conclusion that the high temperature and concentration gradient increase diffusion coefficient and cation migration is right [5, 6] but the fact that most of the effect is limited to crystal edge zones where the diffusive distance is shortest may also favour the shock wave effects. Longer cation migration paths through the whole crystal lattice are slower and more difficult in both cases.

Even if the relatively short duration of both impact and post-impact phases may allow qualitatively similar small Fe,Mg increases and Mn,Ca decreases at garnets' edge zones the heated low-pressure post-impact phase may still be the main period for the garnet-matrix cation diffusion. Especially this is evident in the case of Jänisjärvi impactite where no boundary melt effects are obvious at garnets edges. The the present erosion level and the impactite samples collected from it represent rather deep shock-metamorphic level of the original crater. If in other cases there are found any signs of melting at the egdes of garnet crystals then there have been more possibilities for a more straightforward cation exchange during the impact explosion-related shock-wave or vibration phase as described by Feldman et al. [1].

**References:**

- [1] Feldman, V.I., Arbusova, E.E., Kozlov, E.A., Zhugin, Yu.N., Guseva, E.V. and Korotaeva, N.N. (1996) Vernadsky-Brown Microsymposium 24, Moscow, Abstracts: 25-26.
- [2] Raitala, J. & Halkoaho, T. (1992) Tectonophysics 216: 187-198.
- [3] Mason, B. (1966) Principles of Geochemistry. John Wiley & Sons, NY.
- [4] Raitala, J. & Halkoaho, T. (1995) Lunar Planet. Sci. XXVI: 1151.
- [5] Loomis, T.P. 1983, In S.K.Saxena (ed.) Kinetics and Equilibrium in Mineral Reactions: 1-60. Springer, NY.
- [6] Lasaga, A.C., 1984, JGR 89: 4009-4025.